A weather proof dome to envelop outdoor objects, use of such a dome and a method for protecting outdoor objects.

Field of the invention

A self-supporting weather proof dome to envelop outdoor objects, the dome being of a material and structure that maintains the shape of the dome and clearance between the dome and the enclosed objects characterized in that the dome comprises and inner structure that withstands external pressure forces and an outer structure that through pulling forces on the outer structure holds the inner structure together, which outer and inner structures are not bonded to each other and at least the outer structure is attachable to a base mount.

Background art

Different weather conditions on earth, both on-land an oceans, put demand on some kind of weather protections regarding humans and other sensitive outdoor objects. Mostly it concerns weather protections against heavy wind-loads, rain, snow, arctic temperature, strong influence of sunshine, UV-radiation etc. The type of weather protection units varies but often requires a kind of housing to completely envelop the outdoor objects.

For example, the weather and its effect on outdoor sensitive electronic radio equipment put high demands on some kind of weather protection to ensure equipment functionality.

It is more cost-effective to envelop the sensitive equipment with a dome compared to adding a chemical surface protection layer on each component for outdoor use.

There are two main types of dome constructions, one based on a framework equipped with panels the other refers to self-supporting dome models. In general, frameworks are commonly used in diameters over 4 meters meanwhile self-supporting constructions refer to diameters less than 4 meters.

Two main construction methods, "Single skin" and "Sandwich" models represent self-supporting domes. They are both in plastics made by manually hands-on work, which make them rather expensive to produce.

"Single skin" is the most common and less expensive self-supporting dome construction. It is made of glass-fibre and polyester with gel coat on top, all bonded together. "Sandwich" is based on two very thin plastic structures, sepa-

rated by a laminate of Honeycomb, Divinycell or Rawcell. The two thin plastic structures are bonded together with the laminate. In military applications Rawcell is most common due to less signal gain attenuation compared to the others. However, it is at least a 3 times more expensive material compared to Divinycell. "Sandwich" constructions dominate regarding professional outdoor terminals operating in microwave frequency bands over 10GHz, to meet required functionality and high efficiency.

Both "Single skin" and "Sandwich" domes are very heavy constructions, putting hard demands on the mechanical mounting bed to be stiff enough to carry such a dome. Often, the total mass load of domes exceeds the mass of the item domes are aimed to protect. That puts a very hard demand on the base-mount in terms of mechanical structural strength, being able to carry the dome with the equipment inside without generating mechanical flexibility.

To obstruct geometrical deformation, self-supporting plastic domes are moulded in segments, often named panels. Panels representing two orthogonal curvatures of the characteristic are the most frequent existing models.

In radio communications, electronic equipment is used to transmit and receive radio signals. The higher signal frequency in use, the higher demands on the housing signal transparency. The self-supporting dome is not allowed to affect the transmitting or receiving signal frequencies, especially not in terms of signal gain or cross-polarisation. Due to that, the demands on a self-supporting plastic dome material are extremely high in terms of electrostatics, electromagnetic transparency, and material thickness, meanwhile meeting the hardest environmental weather conditions, generated by wind-loads, temperature and UV-radiation in combination with air pollution.

Mostly, the shape of domes is more or less spherical, often half-spherical standing on a cylinder foot. Primarily, the geometrical shape depends on the intention getting a higher signal beam transparency by a minimum of radio signal reflection and signal gain attenuation through the dome. Secondly, a spherical dome reduces the surface pressure effects, generated by wind-loads. The demands on a self-supporting dome in terms of material structural strength and high signal transparency, in the microwave frequency range, put the terms regarding the choice of plastic dome material. The higher radio signal frequency in use, the less thickness of the plastic dome material can be accepted. In practice, the thickness of the

dome material, in respect to its permeability, never ought to exceed 1/4 of the electromagnetic radio signal wavelength in use. For example 12 GHz refers to a wavelength of 25 mm, which refers to an acceptance of 6 mm thickness of the dome material, in respect to a correction regarding its permeability.

Maritime satellite communication (SATCOM) offering monitoring services represents one of the fastest growing business markets of today and put requests on reliable, small sized self-supporting domes (d <4m) with no impact on the radio microwave frequency signals transmitted cross the dome material. In accordance to SATCOM market requirements and traffic signal frequencies, the self-supporting dome constructions are best meeting the demands.

There even exist a number of other odd constructions offering a kind of weather protection similar to a tent. It is based on a typical framework, covered by a fabric. The fabric is very hard tightened to the framework, which only support the fabric in a few spots. However, this type of technical solution put demands on the fabric to handle heavy wind-loads with a very strong impact on the fabric, often much over the material elastic limit, followed by a material stress, with a collapse as the result. The fabric material fatigue occurs very quickly due to the ongoing material stress caused by friction between fabric and framework, especially in maritime applications under impact from UV radiation, salt and sulphuric air pollutions, the fabric collapse. Sometimes it happens that fabric elasticity causes a geometrical deformation with a concave fabric structure between parts of frameworks under impact from heavy wind-loads, putting the whole dome in motion generating mechanical problems inside the dome, often ending-up with a operational drift-stop.

The invention meets all mentioned known requirements put on a self-supporting weather proof dome to envelop outdoor objects like protecting humans and other sensitive outdoor equipment in terms of thermal insulation, UV-protection, mechanical structural stiffness, rigidity, material stress and permeability. At the same, the invention offers an industrial robotic serial production of domes with a minimum of manual hands-on labor work to produce domes, which dramatically have a great impact on dome production costs. A modest production cost opens a number of new different markets and applications. Except for all maritime applications, the modest production cost makes the self-supporting weather proof dome available to replace ordinary tent models, for example in

arctic expeditions, military applications, but also in rescue and surveillance operations. Primarily, due to the excellent thermal insulation, extremely low weight and simplicity in mounting and demounting on-site, wherever it might be from arctic climate to strong sunshine in deserts, under impact of heavy wind-loads.

Description of the invention

This object has been achieved in that a dome of type specified in Claims no. 1 includes the specific features that the dome comprises an inner structure that withstands external pressure forces and an outer structure that through pulling forces on the outer structure holds the inner structure together, which outer and inner structures are not bonded to each other and at lest the outer structure is attachable to a base mount. The dome construction with an outer structure and an inner structure, not bonded to each other, meet all demands on a self-supporting dome – a weather proof unit - in terms of mechanical structure stiffness, rigidity, material stress, thermal insulation, signal gain attenuation and cross-polarisation etc. The inner structure offers required mechanical structure stiffness and rigidity by offering a geometrical momentum generated by thickness of the inner structure material, consisting of a large number of cells filled with air, giving acceptance to required electromagnetic transmission in microwave frequency bands with a minimum of signal gain attenuation through the inner structure in combination with a good thermal insulation. Further, the dome construction according to the present invention with an outer and inner structure, not bonded to each other, gives an advantage in that it offers an extended surface load compared to other known similar constructions like a tent model described by a number of point loads between a framework and a fabric mounted tightened on top of it generating friction and material stress. All advantages concerning the present invention offers to a minimum of manually hands on labour work investment.

According to an embodiment of the invention that protects electronic equipment a dome characterized in that also said inner structure is attachable to said base mount which offers a fixed position and required clearance between the dome and the enclosed equipment.

Further a dome characterized in that the inner structure includes form rigid cellular plastic makes it available to increase the thickness of the inner structure

material to get required geometrical momentum to withstand external pressure forces on the dome. Meanwhile form rigid cellular plastic consists of a large number of cells filled with air, offering a minimum of signal gain attenuation ref to a microwave signal beam frequency. Due to the cellular plastic material density the total weight of the inner structure becomes extremely low making it easy to handle, reducing the time required to build-up the dome on site, due to simplicity in mounting and demounting. The dome construction with an outer structure and an inner structure not bonded to each other, in combination with a low weight, geometrical structure, mechanical stiffness and rigidity results in a minimum of material stress.

Further a dome characterized in that the outer structure includes a UV-resistant fabric to protect the inner structure from being destroyed by UV radiation improve the dome construction. Especially, as UV-radiation is strong in areas close to the equator, but also on oceans, due to the characteristics of water regarding reflections of UV-beams. As the outer structure is not bonded to the inner structure it makes it easy to replace the outer structure if of some reason it requires. The outer structure fabric can also be provided in different colours to meet individual requirements to a budget cost investment.

Further a dome characterized in that said fabric is a wind-stopper fabric aimed to keep the material structural form, regardless of wind-loads, snow or rain.

Further a dome characterized in that a number of straps are mounted on the outer structure, which straps are attachable to said base mount to ensure a solid mount of the dome to the base mount offers a improved capability to withstand heavy wind-loads connected to stormy weather conditions on oceans.

Further a dome characterized in that said fabric in its lower part is provided with a number of vertically directed expansion chambers integrated into the fabric and being equally spread around the dome, the expansion chambers having a draw function to ensure the fabric to be tighten, enveloping the inner structure, which improves the dome functionality in terms of maximal fitting and by generating turbulence wind streaming around the expansion chambers stopping wind-loads to form and destroy the fabric in stormy weather conditions on oceans.

Further a dome characterized in that said fabric includes a number of zips, each zip extending from a lower edge of the fabric and being directed upwards, preferably up to half of the height of the dome makes it easy to mount the fabric on top of the inner structure, but also making it easy to open, giving access to the

inner structure and a via a hatch entrance to the protected outdoor equipment.

Further a dome characterized in that said cellular plastic has a thickness such that water condensation inside the dome is substantially reduced. The reason is the cellular plastic. It consists of a large number of cells filled with air, offering an excellent and required thermal insulation moving the dew point outwards.

Further a dome characterized in that the dome is provided with means for maintaining a pressure within the dome that slightly exceeds the surrounding pressure, offering an extra protection guard against wind saturated with salt penetrating the outer and inner structure reaching the dome protected outdoor objects.

Further a dome characterized in that the dome is adapted to envelop electronic radio communication equipment in that the materials of the inner and outer structures are such that radio waves are able to penetrate the dome with no harm referred to the permeability of the dome in terms of signal gain attenuation and cross-polarisation.

The invention concerns both an application of the invented dome and to a method fro protecting outdoor objects, in particular electronic radio communication equipment, characterized in that the objects are enveloped in a dome and the pressure within the dome is maintained at a slightly higher pressure than the surrounding pressure.

Description of figures

An embodiment of the innovation is described in connection to enclosed drawings, schematically in accordance to the invention by

Figure 1	shows a principle view of a dome,
Figure 2	shows a part from a side, in an above angle, a structure of pentagonal segments,
Figure 3	shows the same structure as in Figure 2, from above
Figure 4	shows a segment being a part of the structure in accordance to Figure 2-3,
Figure 5	shows a structure consisting of a segment in shape similar to a piece of an orange,

Figure 6 shows a cylinder basement carrying the plastic dome above, in accordance to Figure 2-3 or Figure 5,

Figure 7 shows a part of a modified mechanical joint basement ring, in accordance to Figure 6,

Figure 8 shows a dome from a side with the outer structure in accordance to Figure 5,

Figure 9 shows a dome from a side with the outer structure equipped with three zips, and

Figure 10 shows the outer structure equipped with three expansion chambers as a part of the outer structure.

Detailed description of an embodiment of the invention

The following example of the invention interacting functions composition comprise in accordance to Figure 1 of a dome that has a partly spherical housing 11-12 consisting of an inner structure 11 of a form rigid cellulär plastic and an outer structure 12 of a UV resistant, wind-stopping fabric. Attached to the outer structure 12 there are a number of straps 13-15 mounted to tighten the cellular plastic housing 11-12 to the deck mount. The partly spherical plastic housing 11-12 is fixed mounted in a horizontal, mechanical joint of a cylindrical base ring 16, mounted direct to the base.

An application of a dome, that at the same time fulfil earlier given demands on such a type of weather protection housing unit, preferably can be made of form rigid cellular plastic, without any additives of metal components or flame retardants with a certain impact on the material permeability. In practice, such metal component additives have shown a reduction of using of any plastic material in the electromagnetic axis of the antenna, transmitting microwave radio communication signal frequency. Cellular plastic is an excellent material, fitting well, making a self-supporting housing framework described by a partly spherical dome. The form rigid cellular plastic can preferably be manufactured in smaller segments of double curvature areas and put together to requested geometrical figures by a kind of joint adaptation.

The shown inner surface structure in Figure 2 consists of a number (12 pieces) of pentagonal double curvature segments of cellular plastics mounted together, and Figure 3 show the same inner structure from above.

Figure 4 shows in perspective one of the segments of the inner structure in accordance to Figure 23.

Figure 5 shows the outer structure from a side. The outer structure consists of a number (6 pieces) of long strip vertical segments, in geometric like pieces of an orange.

The base of the plastic housing consists of a mechanical joint of a cylindrical ring, and Figure 7 shows a part of the mechanical joint of the cylindrical ring, consisting of two from the bottom 70 upward stands 71,72. Between these stands the plastic housing bottom part shall be jointly tightened.

Figure 8 shows from a side the outer structure of the plastic housing. The outer structure consists of segments 81,82... like pieces of an orange, equipped with straps 85, 86, 87, 88... with the mission to tighten the housing to the basement.

Figure 9 shows the plastic housing from a side equipped with symmetrical mounted vertical zips 91,92,93... placed around the housing, as a part of the outer structure. The zips are conveniently placed below and from the horizon diameter plane 90-90, giving access to open-up the outer structure, easily.

Figure 10 shows the outer structure equipped with expansion chambers 101,102,103.. vertically mounted around the housing in the lower part of the outer structure, being an integrated part of the same.

The form rigid cellular plastic housing describes the inner structure 11. It almost consists of cells filled of air (c.98%) offering structural mechanical advantages by adding requested material thickness without disadvantages regarding the material permeability. As the outer structure is very thin the form rigid cellular plastic can be substantially thicker offering a geometrical advantage by the thickness generating required mechanical momentum to meet external forces impact on a self-supporting construction concerning heavy wind-loads. Thus the thickness offers required mechanical construction stiffness with less signal gain attenuation compared to known "sandwich" domes can provide to a similar cost.

In general, form rigid cellular plastic is not UV-resistant. It has to be protected by an outer structure, with no impact on the dome permeability. The outer

structure has to be very thin with a minimum of impact on the permeability, meanwhile offering required UV-resistance and mechanical function, for example in a marine environmental application area. Together the form rigid cellular plastic housing and the UV-resistant fabric wind-stopper make a most excellent and cost-efficient dome construction, complete compatible with the most expensive domes of "sandwich" constructions.

As the total mass of the form rigid cellular plastic housing is extremely low, the outer structure of the dome has to be tightened to the base mount by straps to ensure function, even under stormy weather conditions.

The fabric is produced by CAD/CAM to offer a maximal fitting, on top enveloping the cellular plastic housing, becoming the outer structure. The outer structure is UV-resistant with capability to offer maximal protection against material stress and external mechanical forces. At the same, the fabric meets all requests on permeability with a minimum of impact on microwave upper band frequency radio communications. The fabric is equipped with vertical strap interfaces aimed to be tighten to the base mount, for example to a ship deck. The half spherical top of the outer structure fabric housing represents a unit fitting together with the geometrical bottom part. The bottom part of the fabric is vertically and symmetrically equipped with zips. The zips are integrated to the outer structure making it easier to mount on top of the inner structure, the form rigid cellular plastic housing. Further, the tips make it easy to enter inside the dome. A suitable hatch entrance in the form rigid cellular plastic housing, strategically positioned between the zips of the outer structure, open up entering the inside of the dome, for example to maintain and making service on the weather protected electronic radio communication equipment.

In addition, reducing any wind-loads impact on the UV-resistant fabric, a draw frame of expansion chambers are integrated to the fabric tightening the same to a maximal fitting cover on top of the cellular plastic housing.

The draw frame operates by a flexible geometrical cylinder diameter depending on the pressure level in the expansion chambers. The expansion chambers are integrated to the bottom part of the outer structure 12, vertically mounted and separated around the dome offering maximal tension effect. The stretching per extension chambers refers to the difference in cylinder diameter between no pressure and maximal allowed pressure. The expansion chambers consist of a

flexible material integrated to the fabric outer structure, for example a woven polyester plastic containing a flexible gas cylinder, a hose of rubber. Mounted in a flat condition, tight to the fabric outer structure, it will automatically stretch the fabric, as soon as the extension chambers are pressurized, for example with air, as the diameter of a cylinder with a fix circumference always are less then half the circumference, as the ratio refers to [$2<\pi$].

A hose in a flat condition with a width of 30 mm will only have a width less than 20 mm when it is pressurized. It refers to a stretching of about 10 mm (= 30 - 20 mm). The expansion chambers make the fabric stretched, generating a very tight fitting outer structure on the top of the form rigid cellular plastic panel housing.

The expansion chambers vertically mounted around the dome generate turbulent wind streaming, improving the dome stability under impact of heavy wind loads.

The integrated straps offer a fixed dome position against the base mount, for example a deck on a ship. Due to the straps the dome meets the marine environmental conditions, expected on a ship, on a heavy oceans.

The mounted straps, in combination with zips and for example "Velcro tape", result in an easy mounting of the accurate CAD/CAM made UV-resistant fabric outer structure.

The form rigid cellular plastic housing offers an excellent stiffness against indirect action able to resist a surface high pressure, distributed via the fabric outer structure. The friction is extremely high between the stretched fabric and the form rigid cellular plastic housing, due to the CAD/CAM production method offering an extremely good fitting between the double curvature areas in combination with the expansion chambers stretching the fabric to a maximum of tightness.

The combination of the panel structure, self-looking after mounting, support base mount consisting of a mechanical joint offering a reliable base connection, in example a ship-deck, together with the outer UV-resistant structure, manufactured to meet mechanical forces in terms of elongation strain under external forces impact, for example generated by wind-loads, offers together a most functional weather protection housing.

Together with the dome it is recommended to use an electronic weather station circuit card equipped with sensors detecting environmental conditions improving the dome functionality, reducing water-condensation and salt-corrosion on

electronics inside the dome, available due to the excellent thermal insulation and panel seam tightness. The electronic weather station circuit card contains anemometer, barometer, hygrometer and thermometer and circuit breakers for switch on/off fans, intercooler and heating systems. There are two barometer components on the circuit card, one measuring the air pressure outside respectively inside the dome. Together with the anemometer the dynamic surface pressure against the dome is calculated. The air pressure inside the dome will then be adjusted to meet the wind-loads impact on the dome outer structure surface by running the air inlet fans. When the air pressure inside the dome exceeds the calculated pressure data outside, the circuit breaker switch on the electric controlled ventilation pressing out air from inside to outside the dome. The inside air pressure control and guidance gives an extra material structure rigidity under heavy wind-loads with a mechanical impact on the dome by rain or snow.

Primarily, the method to increase the air pressure inside the dome refers to a requirement to protect against salt-corrosion by ocean air saturated with salt, penetrating the dome. By the hygrometer the relatively air humidity inside the dome is controlled and set to be about 50 - 55%. The relatively humidity controls & guidance by the electronic weather station in mission to reduce the origin of salt-corrosion, especially with focus on the electronic RF radio communication components, hereby protected inside the dome.

In this example described plastic housing offers an excellent weather protection, complete comparable with the most technically advanced domes available on the business market, but in this case to a dramatically lower production cost. The plastic housing has required mechanical rigidity, low weight, low production cost, reduced transport expenses, extremely low signal attenuation in the microwave frequency upper band, simple and quick installation on site, spare parts to a budget cost, stabilized temperature and relative air humidity inside the dome with no risk for icing and automatic air pressure governor.